Distr.
LIMITED

ID/WG.431/14
3 April 1985

ENGLISH

United Nations Industrial Development Organization

Symposium on the Importance of Lactic Acid Fermentation
in the Food Industry

Mexico City, Mexico, 27 - 29 November 1984

RECYCLING AGROINDUSTRIAL WASTE BY LACTIC FERMENTATIONS: COFFEE PULP SILAGE*

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V.85-24795

CONTENTS

		Page
I.	BACKGROUND	1
II.	INTRODUCTION	2 - 5
III.	EXPERIMENTS	5 - 6
IV.	RESULTS AND DISCUSSIONS	6 - 11
	Table 1: Chemical Composition of Coffee Pulp	12
	Table 2: Quality of Coffee Pulp Silage	13
	Table 3: Effect of Ensiling on Chemical Composition of Coffee Pulp	14
	Table 4: Fatty Acid and Lactic Acid Formation	15
	Fig. 1: Coffee producer areas of Venezuela	16
	Fig. 2: Schematic diagram for the production of ensiled coffee pulp using drying system from existing coffee processing plant	17
	REFERENCES	18 - 21

I. BACKGROUND

A biotechnological process to make use of coffee pulp for animal feeding has been developed. The process can be adapted to the existing coffee processing plants for drying the product once harvesting time has finished. Unit operations involved are: pressing (optional), silaging, liming and drying.

Experimental work demonstratesthat if the operation silaging is adequately handled, coffee pulp can be maintained over 100 days without signs of putrefaction. This length of time is usually equivalent to the actual Venezuelan coffee harvesting time. However, if molasses are added to the fresh pulp the silage quality can be strongly improved. Experimental results from 60 days coffee pulp silaged at the above conditions showed fatty acids and lactic acid formation of the following composition (g./100 g. of dry matter): acetic, 4.33; propionic, 0.46; isobutyric, 0.046; n-butyric, 1.52; isovaleric, 0.03; n-valeric, 0.12, and lactic acid, 1.12. Coffee pulp silage experimental production has been already suggested to local Venezuelan planning office in order to get some more technical information for both nutritional and economical feasibility studies.

II. INTRODUCTION

The process of ensilage is an alternative traditionally used in some European countries, to the drying of green crops for winter feeding of cattle and sheep. In tropical countries it can be used to keep feed during extreme sunny and rainy seasonal periods such as drought and flood, respectively.

The process involves the controled fermentation of green crops such as grass, maize and some others available by products from agriculture activities. Molasses is sometimes added to promote fermentation and increase palatability (Hawker and Linton, 1971; Checa España, 1966). As the fermentation proceeds the temperature rises and the product becomes more acid. The acidity prevents the growth of many putrefactive organisms and as the oxygen is consumed strict aerobes microorganisms are inhibited. Only facultative and strict anaerobes continue to grow. At first, species of E. coli and Aerobacter predominate, but as the pH falls these are replaced by lactobacilli and streptococci; which ferment the plant material to produce lactic, butyric, propionic, acetic acids and some others substances, which give flavours pleasant to animals. Under these conditions an stable product is obtained. However, for good silage it is important that the fermentation produces mainly lactic acid. In this sense, several processes have already patented (Gutcho, 1973; Sodano, 1979). One of the agroindustrial residues available in some tropical countries, which has not had further uses other than soil enhancer is the coffee pulp coming from wet coffee processing plants.

Wet agroindustrial coffee processing plants, usually have been considered to cause various environmental problems due to high strengh of the biochemical oxygen demand (BOD) on their effluents (Rolz et al, 1975),

BOD removing from liquid wastes can be made by using aerobic oxidation lagoons, however this type of treatment can be so expensive to small coffee producers. Organic matter contained in liquid wastes can be used as a substrate to produce microbial protein (Rolz et al, 1975)or bio-gas in some countries where there are protein and energy deficits. Likewise, coffee solid wastes such as a coffee pulp can be easily converted to compost or to substitute conventional and expensive components of feed.

Coffee pulp can be seen as an attractive raw material for feeding since high amounts of it can be obtained from coffee processing plants. Otherwise, it will contribuite to enhance environmental problems such as a putrefaction, insect attractions and unpleasant odor formations (Ferrer and Carrizales, 1984).

Venezuelan coffee production was by 1983 nearly 60.000 metric tons (Anon. 1983), therefore it can be estimated from the above figure a production 150.000 metric tons of wet coffee pulp. Most of this production is highly concentrated in the west of this country, where an intensive agriculture and cattle raising high-land is taking place (Fig. 1). Therewith coffee pulp may be used as a soil conditioner or

as raw material for animal feed production. This last alternative looks more attractive since land limitation can affect the production of conventional forages in these areas.

Since coffee pulp has an adequate chemical composition of total sugars, protein and cellulose (table 1), it could be used as a substrate for microbial protein production (Calle, 1974; Rolz et al, 1975) and as feed to ruminants (Braham et al, 1973). Several workers from the Instituto de Nutrición de Centro América y Panamá (INCAP) have strongly suggested the latter alternative. They focused the use of dried fresh and dried silage coffee pulp to substitute high nutritional value of conventional feed at levels up to 20 to 30% dry weight (Cabezas et al, 1978). INCAP method for ensiling coffee pulp is as follows: fresh pulp with a high humidity content (80-85%) is partly sun dried or pressed to remove water up to 65 to 75%, and then it is adequately ensiled (Murillo, 1978), Since most of the water soluble components such as sugars, can be removed by pressing, it seems that ensiling fresh coffee pulp can be more appropriate to guarantee an adequate anaerobic fermentation process (Bohkenfor and Fonseca, 1974). Furthermore, in those areas where others agroindustrial residues are available, they can be combined to get an appropriate humidity for ensiling such as it has been suggested by Checa España (1966); Murillo et al (1976).

Several silo designs have been used for coffee pulp silaging

such as trench, pit and they should contain nearly 961-1057 kg. of coffee pulp/m^3. Molasses can also be added to level up to 5% to guarantee rapid changes to acid pH (Murillo, 1978; Checa España, 1966).

III. EXPERIMENTS

Bench scale

Coffee pulp was provided from a coffee processing plant located nearby CIEPE. Bench scale silage experiments were made on plyethylene bags as containers for 5 kg. of fresh coffee pulp. 5 differents treatments were made to evaluate silage product. Random samples were taken from each treatment at the 23, 51, 82 and 99 days of ensiling time. Treatments were as follows: A, fresh coffee pulp; B, pressed coffee pulp; C, as B + 20 ml of 4% H_2SO_4; D, as C + lactobacillus culture to get a final cell concentration of 10^6 colonies per gram of coffee pulp; E, as B + lactobacillus culture. Sulphuric acid was added to get a final pH of 3.5. Cell suspension was provided by microbiology laboratory.

Samples from 99 days of ensiling time were analysed for protein, fiber, fat, ash, free-nitrogen extract and cafein. Similar analysis were made in samples without any treatment.

Pilot plant scale

Pilot plant experiments were made using 200 liters drums. Each of them was provided with sealed cover on top and a

drilled disk nearby the bottom to drain excess of free water formed during silaging. Each silo was filled with fresh coffee pulp with 3% molasses added, unless otherwise specified. Silos were open at 2 and 4 months for fatty and lactic acid evaluation on silaged product.

Analytical methods

Humidity, ash, fiber, protein, free-nitrogen extract were analysed by standard methods (AOAC, 1980). Caffeine was determined by a gravimetric method (Pearson, 1976); fatty acids and lactic acid were evaluated by chromatographic techniques (Anon., 1975).

IV. RESULTS AND DISCUSSIONS

Table 2 show silage experiments made on 5 kg polyethylene bags. It can be observed that treatment A showed pH lower than 4 and good smell. The remaining treatments demonstrated poor quality such as: mold and worms growth, unpleasant odors, black colour, etc. Mold growth indicated that bags were not completely oxygen sealed, therefore they should not be used for future experiments. It appears that glass jars could be more appropriate to these experiments. It may be possible that sugars were almost consumed by aerobic organisms such as mold and bacteria once silage started. Therefore, anaerobic fermenting bacteria could be growth limited. Also, as it can be observed from table 2 that fresh coffee pulp (without pressing) was more appropriate for silaging experi-

ments. This is remarkable related to the initial pulp coffee sugar content, which can guarantee of an adequate substrate to the anaerobic bacteria (Bohkenfor and Fonseca, 1984). Treatments made with lactic acid bacteria addition were probably affected by the lack of sealing in the bags as once the pH was reduced such was observed on samples from 23 days of silaging, that pH started to increase and finally there was putrefaction on samples from 82 and 99 days of silaging time. It seems that if pressed pulp is used, extra sugars should then be provided (Checa España, 1966). The effect of silaging on chemical composition of coffee pulp is shown in table 3. It appears that protein, fiber, ash are greatly increased during silage. Protein increase could be due to microbial growth from sugars and mineral nitrogen present on pulp. Increases of protein were previously reported by Murillo (1978). Fat content of fresh pulp was also greatly reduced during silaging. Fat could be used by microorganisms as carbon source. Caffeine was slightly reduced, however this is highly appreciatedsince this component could cause metabolic changes on ruminants physiology (Cabezas et al, 1978). The addition of molasses for agroindustrial residues silaging has been strongly recommended (Checa España, 1966). Molasses addition on coffee pulp silaging has already been used by Murillo (1978).

Experiments with 3% molasses addition on coffee pulp were made to evaluate fatty and lactic acids formation during

2 and 4 months of silaging time. An experiment without molasses addition was also carried out during two months of silaging time. Table 4 shows that coffee pulp without silaging already contained acetic, butyric and lactic acid. These components could be developed on the pulp during handling and transportation from coffee process plant to the laboratory.

Coffee pulp silaged without molasses during two months revealed higher formation of acetic, butyric and lactic acid, indicating that anaerobic process took place. Furthermore, propionic and valeric acids were also detected. Fatty acids are generally produced at anaerobic conditions by clostridia, propionic and lactobacilli bacteria (Gómez, 1981). Hetero-fermentative lactic acid bacteria also produce acetic acid as a metabolic product (Eskin et al, 1973). The level of undesired butyric acid on two months ensilaged coffee pulp without and with molasses addition were 14.9 and 17.8% of the total acids, respectively. However, when ensiling was extended to 4 months it came to 6%. It seems that long ensiling period tend to reduce fatty acids and increase lactic acid. During these experiments, acetic acid predominance was always observed. High level of acetic acid should not be a problem for silage quality since it could be removed during drying operations.

These results can be considered useful for designing ensiling process without molasses addition since lactic acid production rose up to 1.64%. This level of lactic acid

could be appropriated to enhance flavours on silage coffee, however butyric acid appears to be high. Similar levels of lactic acid formation have already been reported on nitrogen enriched glucose medium innoculated with cow dung as a source of lactic acid bacteria, however other acids were not analysed (Gómez and Viniegra, 1980). Molasses addition is always convenient to be used on silaging operation since it can guarantee rapid acidification within less than three days (Gómez and Viniegra, 1980). Experiments with 1% molasses addition of fresh coffee pulp revealed pH reduction from 6.3 to 4 within four days of silaging time (Ferrer, 1984). However molasses addition for silaging would increase operation costs. It may be possible to obtain coffee silage without addition of molasses if adequate oxygen sealing conditions are provided at silos level. This last criteria is sometimes difficult to carry out from the practical point of view. Therefore, it should be more convenient to use molasses in order to guarantee a fast acidification. In this sense desirable fatty and lactic acids may be formed and putrefaction avoided.

Since fresh coffee pulp has a high humidity it is recommendable to mix it with other agroindustrial residues locally available, such it has been suggested by Murillo et al (1966). Even more, sometimes it should be necessary to use some addtives to control the growth of undesirable microorganisms such as butyric acid producers (Sodano, 1979). Research still to be made to find out some others

methods to guarantee an adequate and economic coffee pulp silage production.

Based on the above results a process to preserve fresh coffee pulp has been suggested. It involves the ensiling of coffee pulp throughout harvesting time and later drying the product using available facilities on existing coffee processing plant once coffee harvest has finished (Fig. 2). Actually a similar procedure has already been recommended to a local coffee processing plant to make use of coffee pulp for ruminant feeding. By using this method no extra investment has to be made for drying operations. Even once harvesting time ha finished sun drying may also be used, especially in those geographic regions where the dry season period is later than coffee harvesting time. Local sun drying of silaged coffee pulp can be made on cement yard within 24-30 hours during dry season (Ferrer, 1984; Molina, 1978). Any one drying system adopted, liming operation should be made to avoid both equipment corrosion and cement yard deterioration. Almost 3 kg of lime ($Ca(OH)_2$) should be added to each 100 kg of silaged coffee pulp previous to the drying operation.

It seems that further experiments still have to be made on silaging operation in order to reduce undesired fatty acid formation. In this sense it is necessary to investigate the use of some others additives, which could reduce butytic acid formation. It is strongly suggested to start semicommercial production of coffee pulp silage to investigate

animal behaviour on feeding experiments. Economical feasibility studies are also recommended.

It seems that the above procedure for making use of coffee pulp should contribute to reduce environmental problems, nearby existing coffee processing plants, and to guarantee extra supplies of feeds for animal feeding in all of those geographic regions, where both environmental pollution and food shortages are taking place.

Table 1: **Chemical Composition* of Coffee Pulp**

Component	g/100 dry matter
Humidity	12.6
Dry matter	87.4
Fiber	21.4
Total protein (N x 6.25)	11.2
Ash	8.3
Free-nitrogen extract	15.8
Tannins	1.80-8.56
Pectic compounds	6.5
Total sugars	14.4
Caffeine	1.3
Chlorogenic acid	2.6
Total cafeic acids	1.6

* Elias Luiz (1978).

Table 2; **Quality of Coffee Pulp Silage**
5 Kg. bags. Silage time: 99 days
(Carrizales and Gonzáles, 1984)

Treatment*	Remarks	Silage Time (days)				
		0	23	51	82	99
A	pH	7	3.8	3.7	3.7	3.6
	quality	—	IMG, GS	GS	GS	GS
B	pH	7	3.8	3.7	4.4	3.8
	quality	—	IMG	W	IMG, W	GS
C	pH	3.5	4.0	3.6	3.7	3.8
	quality	—	BS	GS	IMG, GS	BS
D	pH	3.5	4.2	5.1	3.9	ND
	quality		IMG	W	GS	BS
E	pH	7	3.0	3.9	6.2	ND
	quality	—	SMG	W, GS	BS	BS

ND: Non determined.

*A, fresh coffee pulp; B, pressed coffee pulp; C, pressed coffee pulp + H_2SO_4; D, pressed coffee pulp + *lactobacillus* sp. + H_2SO_4; E, pressed coffee pulp + *lactobacillus* sp.

SMG: scarce mold growth
IMG: intensive mold growth
W : worms
GS: good smell
BS: bad smell

Table 3: **Effect of Ensiling on Chemical Composition of Coffee Pulp****. Ensiling time: 99 days. (Carrizales and Gonzáles, 1984)

Component	Dried Fresh Pulp	Dried Ensiled Pulp*
Protein, %	11.57	13.55 ± 0.27
Fiber, %	15.24	17.16 ± 1.13
Fat, %	5,00	2.17 ± 0.26
Ash, %	6,67	8.08 ± 0.84
Free-nitrogen extract, %	61.21	58.50 ± 1.40
Caffeine, ppm	9.496	8.225 ± 4.93

* pH in all treatments was 3.6: unpleasant smell was not presented in treatment A.

** Coffee pulp was not pressed.

Table 4: **Fatty Acid and Lactic Acid Formation** (grams/100 gram dry matter) **During Coffee Pulp Ensiling with 3% Molasses.** Fermentation System: 200 litre anaerobic fermenter (Ferrer, 1984).

Fatty Acid	Ensiling Time (Months)			
	0*	2**	2	4
Acetic	0.540	2.20	4.33	3.31
Propionic	ND	0.58	0.96	0.49
Isobutyric	ND	ND	0.05	ND
n-butyric	0.04	0.79	1.52	0.41
i-valeric	ND	ND	0.34	ND
n-valeric	ND	0.06	0.12	ND
Lactic	0.29	1.64	1.19	2.56
Total acids	0.87	5.27	8.51	6.77

ND: Non detected

* Fresh coffee pulp

** Molasses was not added.

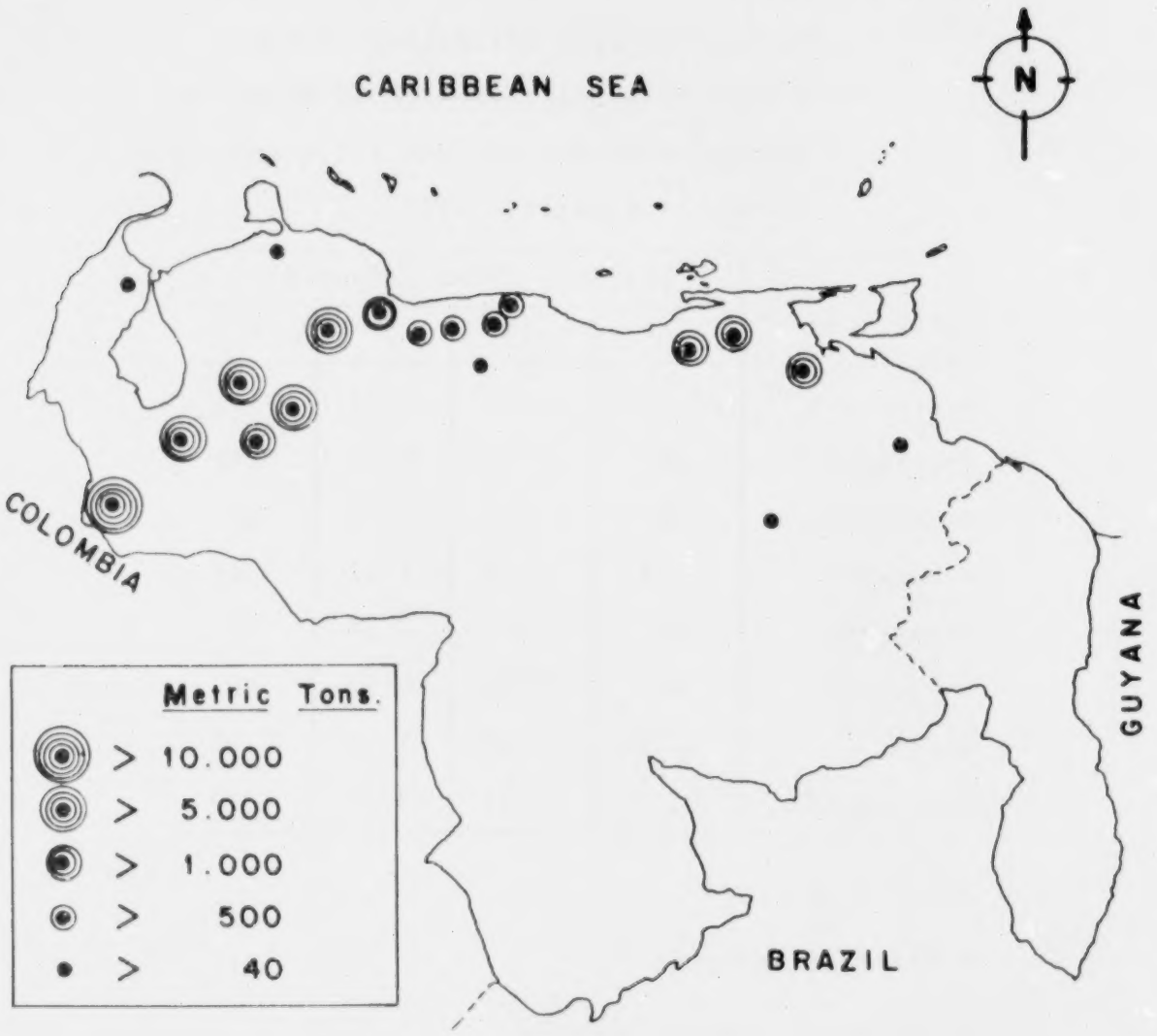

Fig. 1: Coffee producer areas of Venezuela (Anon., 1983)

The boundaries shown on this map do not imply official endorsement or acceptance by the United Nations.

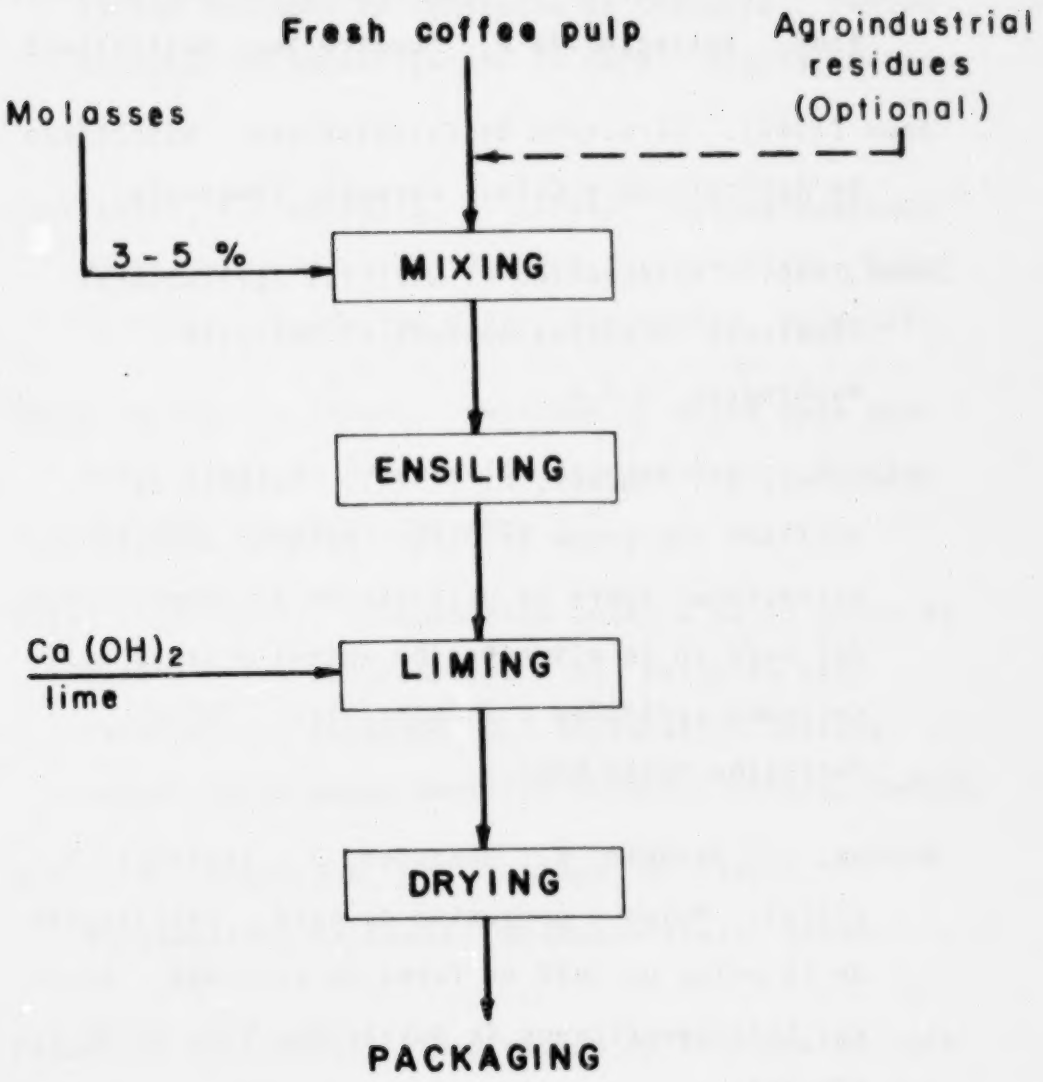

Fig. 2: **Schematic diagram for the production of ensiled coffee pulp using drying system from existing coffee processing plant** (Carrizales, 1984)

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